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Suzuki et al.
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[45] Date of Patent: Jun. 3, 1986

[54] IMAGE FORMING APPARATUS WITH CONTROL FOR IMAGE FORMING CONDITIONS

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[73] Assignee: **Canon Kabushiki Kaisha**, Tokyo, Japan

[21] Appl. No.: **692,048**
[22] Filed: **Jan. 16, 1985**

Related U.S. Application Data

[63] Continuation of Ser. No. 360,684, Mar. 22, 1982.

[30] **Foreign Application Priority Data**

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Apr. 1, 1981	[JP]	Japan	56-47239
Apr. 1, 1981	[JP]	Japan	56-47240
Apr. 1, 1981	[JP]	Japan	56-47241

[51] **Int. Cl.**[4] **G03G 15/00**
[52] **U.S. Cl.** .... **355/14 R**; 355/14 CH; 355/3 R
[58] **Field of Search** .... 355/3 R, 14 CH, 14 R, 355/14 D, 14 E

[56] **References Cited**

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Primary Examiner—A. C. Prescott
Attorney, Agent, or Firm—Fitzpatrick, Cella, Harper & Scinto

[57] **ABSTRACT**

There is disclosed an image forming apparatus capable of compensating for fluctuations in the image forming conditions thereby ensuring optimum image formation. The image forming apparatus is provided with a control for modifying outputs from a processor for image formation when the length of pause in the image formation operation of the processor exceeds a predetermined value.

15 Claims, 13 Drawing Figures

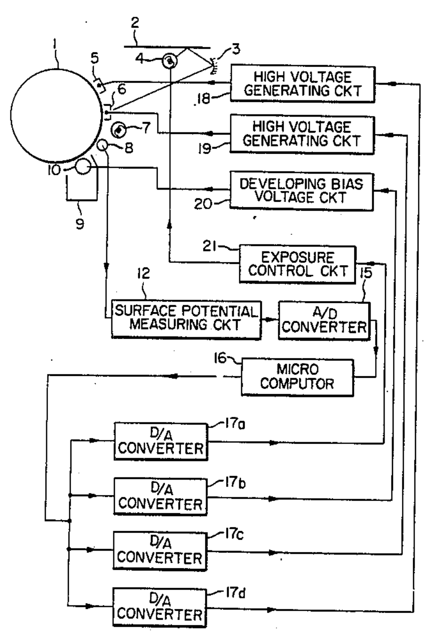


FIG. 1

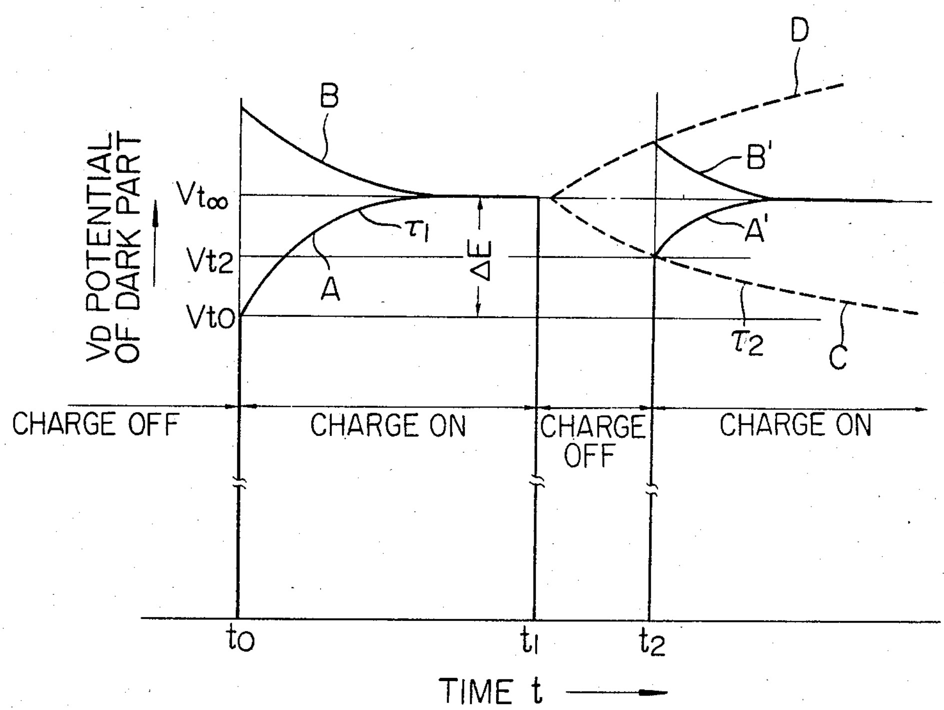
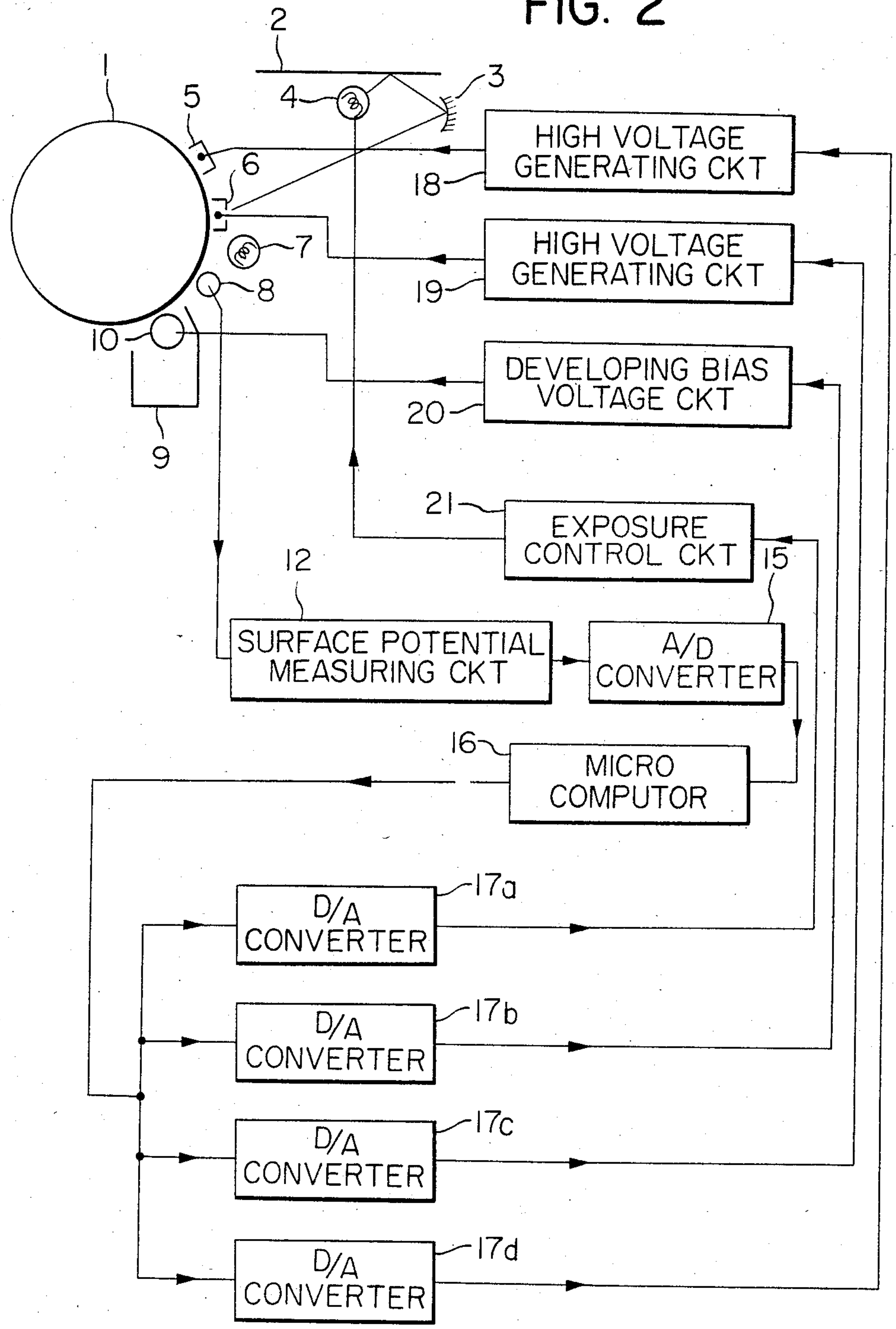

D
B
B'
A'
A
Vt∞
Vt2
Vt0
τ1
τ2
ΔE
C
VD POTENTIAL OF DARK PART
CHARGE OFF
CHARGE ON
CHARGE OFF
CHARGE ON
t0
t1
t2
TIME t

FIG. 2



2
1
5
4
3
6
7
8
10
9
HIGH VOLTAGE GENERATING CKT
18
HIGH VOLTAGE GENERATING CKT
19
DEVELOPING BIAS VOLTAGE CKT
20
21
EXPOSURE CONTROL CKT
15
12
SURFACE POTENTIAL MEASURING CKT
A/D CONVERTER
16
MICRO COMPUTOR
17a
D/A CONVERTER
17b
D/A CONVERTER
17c
D/A CONVERTER
17d
D/A CONVERTER

FIG. 3

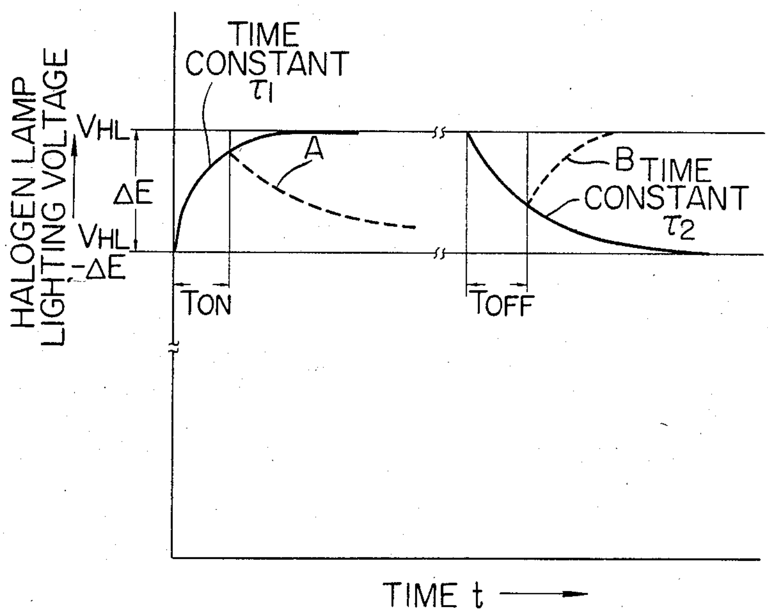

TIME
CONSTANT
τ1
VHL
A
ΔE
VHL
-ΔE
HALOGEN LAMP
LIGHTING VOLTAGE
TON
TOFF
B
TIME
CONSTANT
τ2
TIME t

FIG. 4

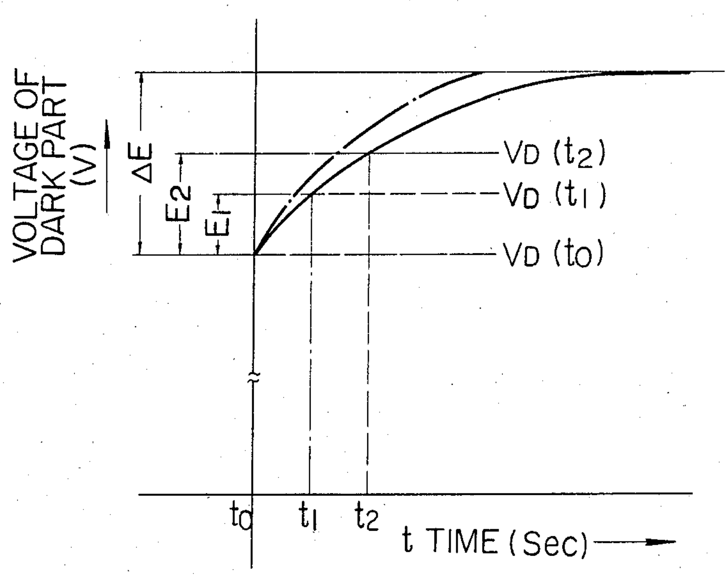

VOLTAGE OF
DARK PART
(V)
ΔE
E2
E1
VD (t2)
VD (t1)
VD (t0)
t0
t1
t2
t TIME (Sec)

FIG. 5

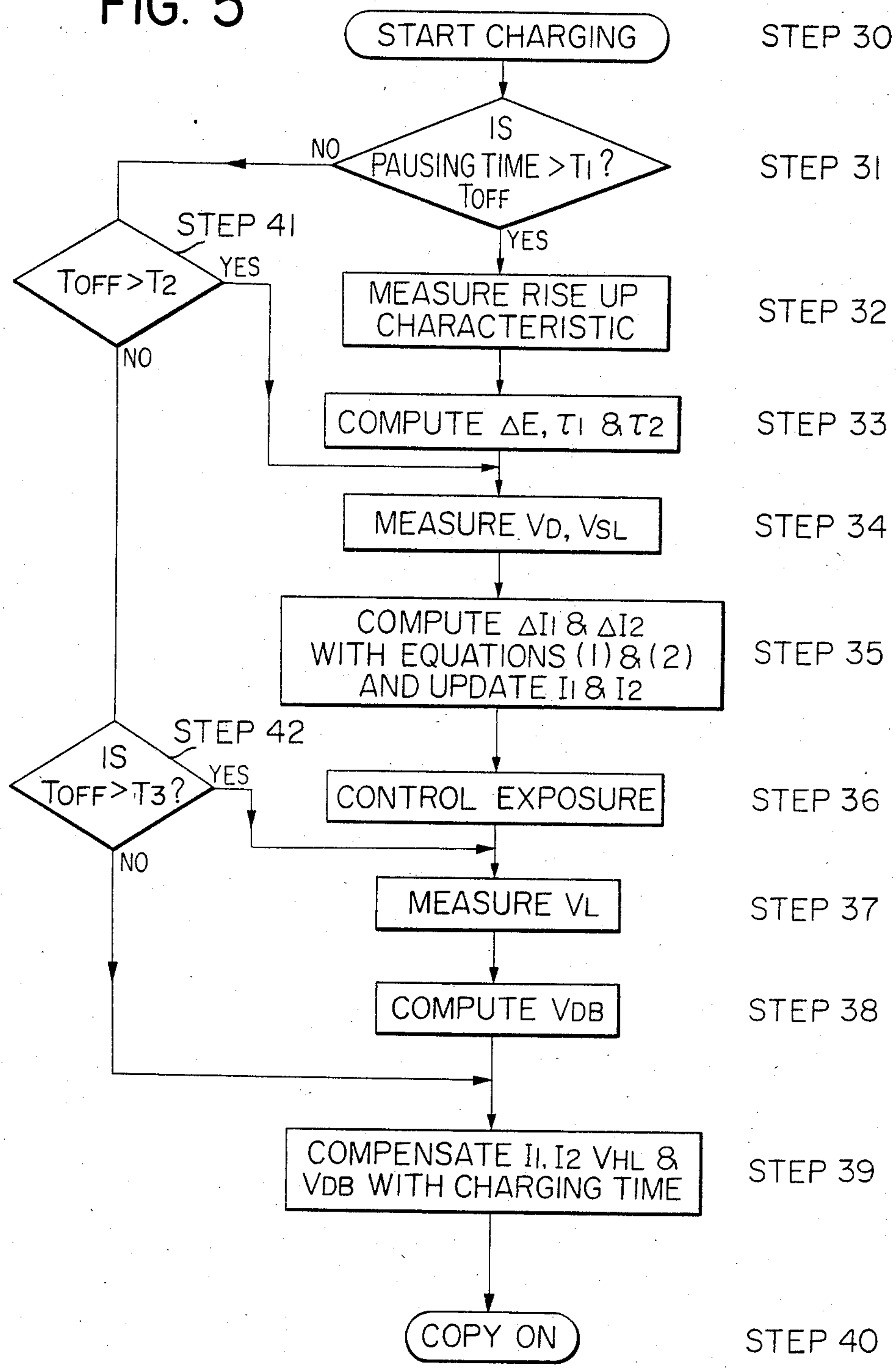

START CHARGING
STEP 30
IS PAUSING TIME > T1 ? TOFF
STEP 31
NO
YES
MEASURE RISE UP CHARACTERISTIC
STEP 32
COMPUTE ΔE, τ1 & τ2
STEP 33
MEASURE VD, VSL
STEP 34
COMPUTE ΔI1 & ΔI2 WITH EQUATIONS (1) & (2) AND UPDATE I1 & I2
STEP 35
CONTROL EXPOSURE
STEP 36
MEASURE VL
STEP 37
COMPUTE VDB
STEP 38
COMPENSATE I1, I2 VHL & VDB WITH CHARGING TIME
STEP 39
COPY ON
STEP 40
STEP 41
TOFF > T2
YES
NO
STEP 42
IS TOFF > T3?
YES
NO

FIG. 6

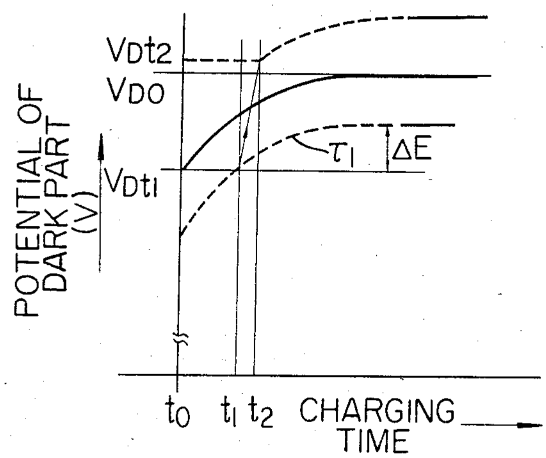

VDt2
VDO
POTENTIAL OF DARK PART (V)
VDt1
τ1
ΔE
t0 t1 t2 CHARGING TIME

FIG. 7

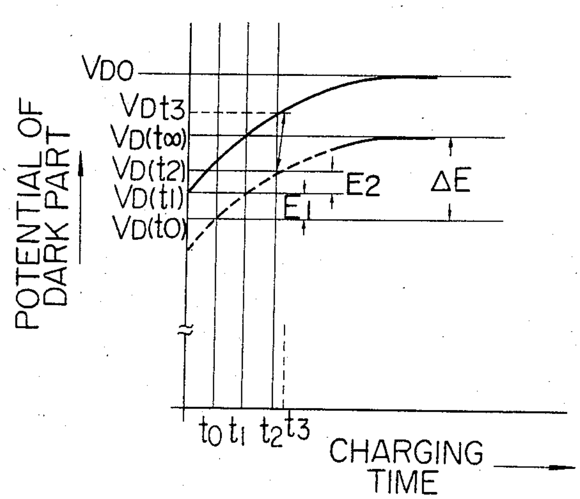

VDO
VDt3
VD(t∞)
VD(t2)
VD(t1)
VD(t0)
POTENTIAL OF DARK PART
E2
ΔE
E1
t0 t1 t2 t3 CHARGING TIME

FIG. 8

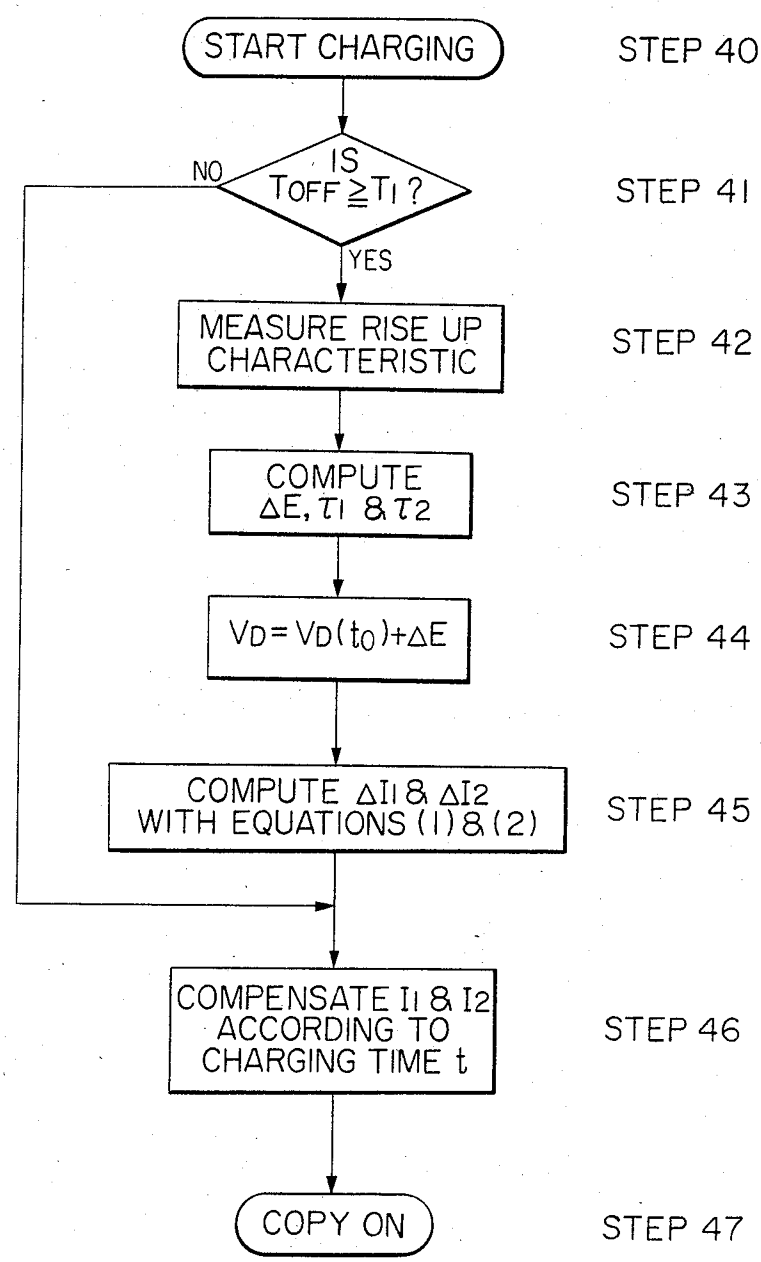

START CHARGING
STEP 40
IS TOFF ≧ T1 ?
NO
YES
STEP 41
MEASURE RISE UP CHARACTERISTIC
STEP 42
COMPUTE ΔE, τ1 & τ2
STEP 43
VD = VD(t0)+ΔE
STEP 44
COMPUTE ΔI1 & ΔI2 WITH EQUATIONS (1) & (2)
STEP 45
COMPENSATE I1 & I2 ACCORDING TO CHARGING TIME t
STEP 46
COPY ON
STEP 47

FIG. 9A

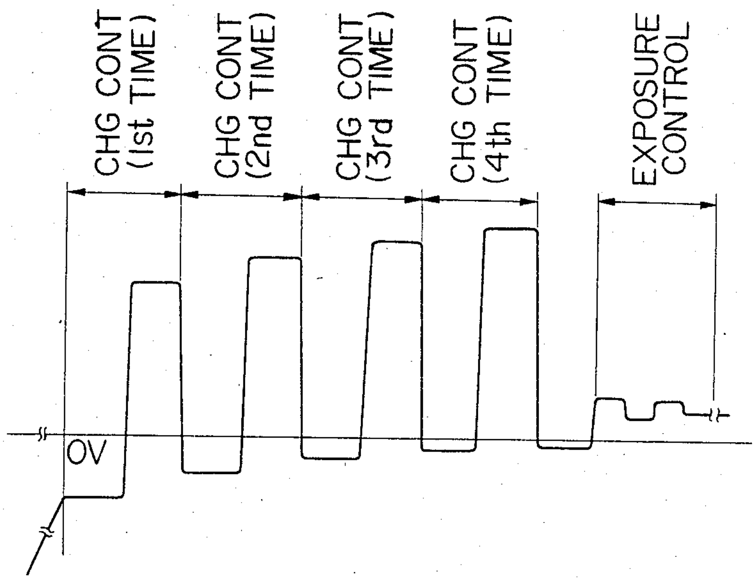

CHG CONT (1st TIME)
CHG CONT (2nd TIME)
CHG CONT (3rd TIME)
CHG CONT (4th TIME)
EXPOSURE CONTROL
OV

FIG. 9B

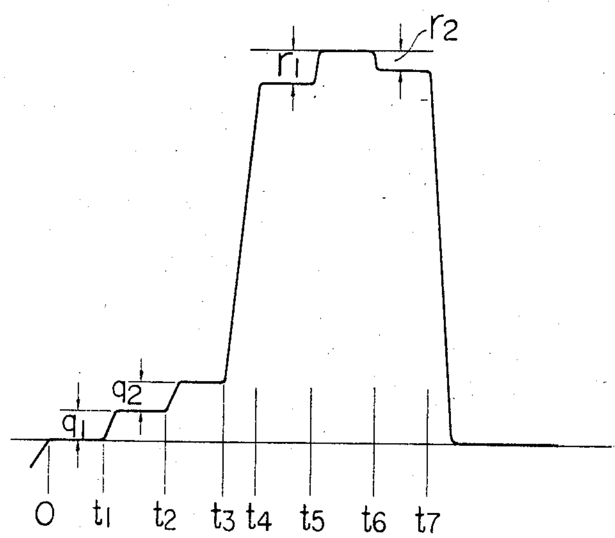
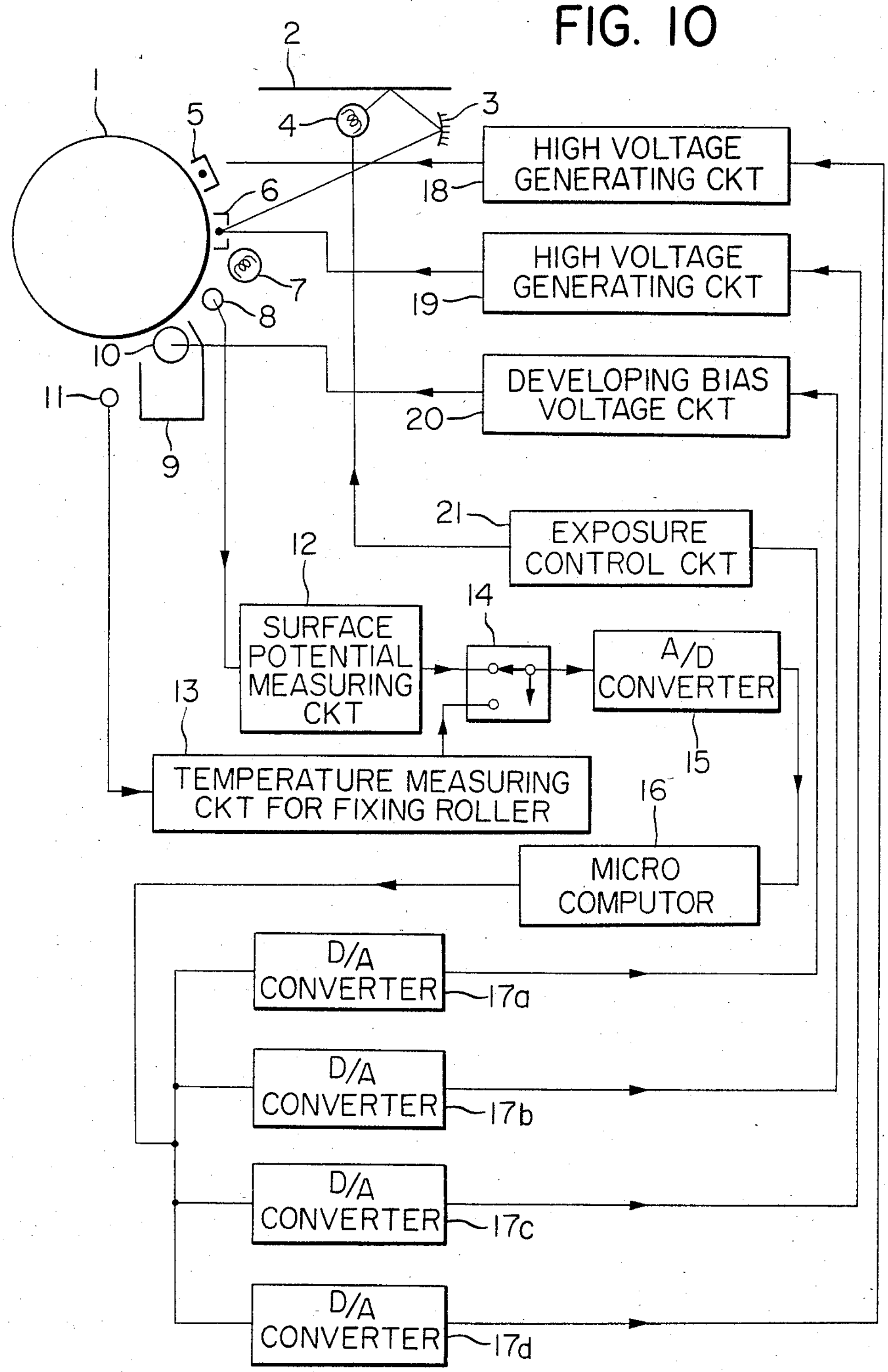

r1
r2
q1
q2
O
t1
t2
t3
t4
t5
t6
t7

FIG. 10



1
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11
HIGH VOLTAGE GENERATING CKT
18
HIGH VOLTAGE GENERATING CKT
19
DEVELOPING BIAS VOLTAGE CKT
20
21
EXPOSURE CONTROL CKT
12
SURFACE POTENTIAL MEASURING CKT
14
A/D CONVERTER
15
13
TEMPERATURE MEASURING CKT FOR FIXING ROLLER
16
MICRO COMPUTOR
D/A CONVERTER
17a
D/A CONVERTER
17b
D/A CONVERTER
17c
D/A CONVERTER
17d

FIG. 11B

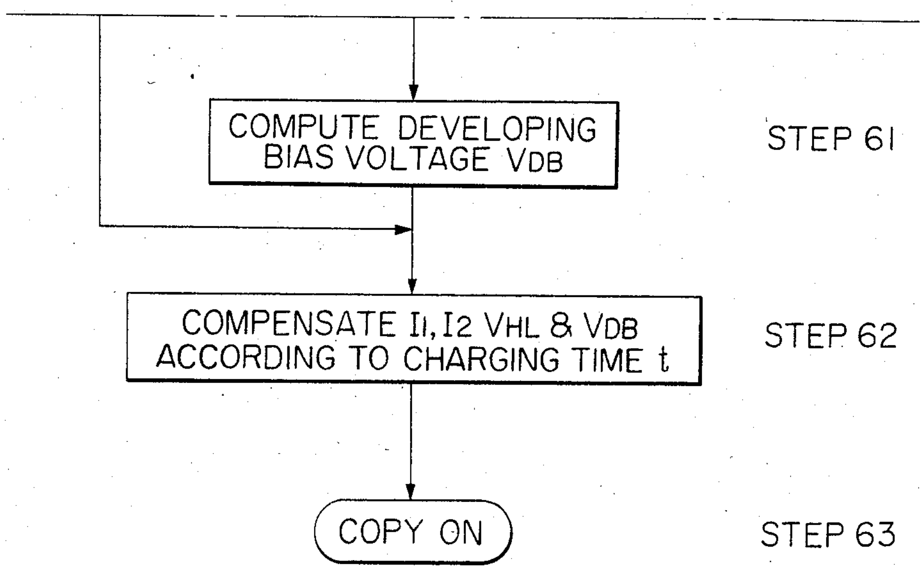

FIG. 11

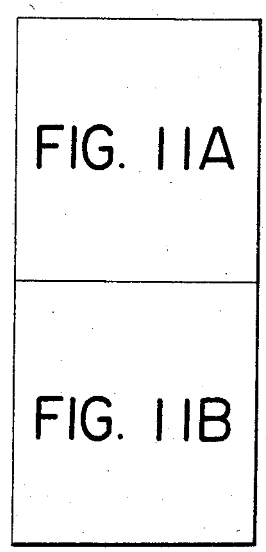

FIG. 11A

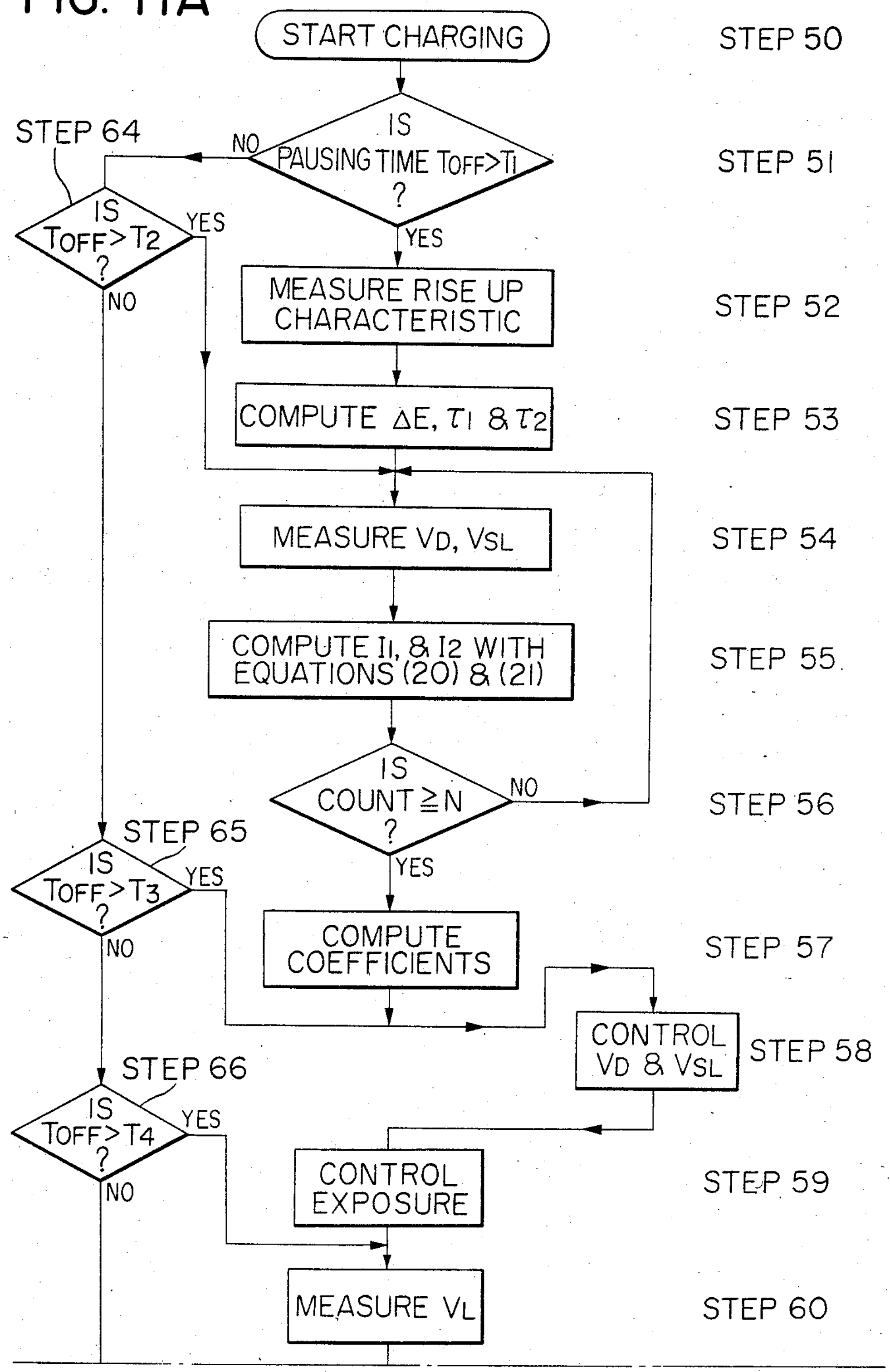
START CHARGING
STEP 50
IS PAUSING TIME TOFF>T1 ?
STEP 51
NO
YES
STEP 64
IS TOFF>T2 ?
YES
NO
MEASURE RISE UP CHARACTERISTIC
STEP 52
COMPUTE ΔE, τ1 & τ2
STEP 53
MEASURE VD, VSL
STEP 54
COMPUTE I1, & I2 WITH EQUATIONS (20) & (21)
STEP 55
IS COUNT ≧ N ?
NO
YES
STEP 56
STEP 65
IS TOFF>T3 ?
YES
NO
COMPUTE COEFFICIENTS
STEP 57
CONTROL VD & VSL
STEP 58
STEP 66
IS TOFF>T4 ?
YES
NO
CONTROL EXPOSURE
STEP 59
MEASURE VL
STEP 60

IMAGE FORMING APPARATUS WITH CONTROL FOR IMAGE FORMING CONDITIONS

This is a continuation of application Ser. No. 360,684, filed Mar. 22, 1982.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image forming apparatus for image formation on a sheet, such as a copier.

2. Description of the Prior Art

Conventional electrostatic recording apparatus such as electrophotographic copiers have been associated with the drawbacks that the charging characteristics of the recording member, i.e. photosensitive drum, are affected by environmental parameters such as moisture and also by time-dependent changes such as mechanical fatigue during use.

In order to compensate such environmental or time-dependent effects, there has been proposed a method of controlling the image recording conditions such as the conditions of charging, exposure, developing etc. to attain optimum formation in response to the detected potential of the latent image formed on the photosensitive drum, or a method of controlling the conditions of charging and exposure in response to the charging period to attain optimum image recording.

Such conventional methods are however defective in that the apparatus becomes inevitably expensive since the detector for the surface potential is complicated and expensive.

Also such conventional methods are unable to compensate for a rapid fluctuation in the charging characteristic of the photosensitive drum immediately after the start of electrostatic charging. Such fluctuation will hereinafter be referred to as initial fluctuation.

Said initial fluctuation of the photosensitive drum, a phenomenon that the charging characteristic shows a rapid fluctuation during a short period immediately after the start of electrostatic charging due to the past charging hysteresis before it reaches a stable state, has become a problem in recent years since the idle waiting time in the copiers has become limited due to the increasing copying speed. As shown by a curve in FIG. **1**, the dark potential V_D, which is a drum surface potential formed by an exposure corresponding to a dark image area, shows an exponential change from an initial value Vt_0 to a final value Vt_∞ according to a time constant τ_1 when the charging is initiated at t_0 after a sufficiently long pause. Said potential change may appear in inverted form as represented by a curve B depending on the charging hysteresis, i.e. the charging state when the preceding charging is terminated.

Also if the charging is initiated for example at t_2 after an insufficiently long pause, the surface potential shows a change with the same time constant τ_1 from a different initial value (Vt_2) to the afore-mentioned final value Vt_∞, as shown by a curve A' or B'. Consequently the charge starting voltage varies from Vt_∞ to Vt_0 with a time constant τ_2 ($>\tau_1$) as shown by curves C and D in FIG. **1**. In such situation the potential difference $\Delta E = Vt_\infty - Vt_0$ and the time constants τ_1, τ_2 vary according to the charging hysteresis and environmental parameters, particularly humidity, and show fluctuations among different production lots of the photosensitive drum. Such initial fluctuation of the potential causes a density difference between the first and second copies or within a copy.

Also such conventional control methods are not effective enough since a predetermined control factor is always used even for the deterioration of the photosensitive drum or a slow change in the environmental parameters, and are therefore unable to provide optimum image recording conditions. Furthermore, in such methods it is difficult to realize the desired recording conditions through frequently repeated control steps since the control procedure is not real-time and since the lamp utilized for forming light and dark image areas requires relatively long starting and extinguishing periods. Furthermore the eventual fluctuation of the characteristic between different production lots of the photosensitive drum necessitates lengthy adjustment procedure at each drum replacement in order to compensate the difference between the drum characteristic and the control factor, and such difference may retard the establishment of the optimum conditions or cause an excessive compensation giving rise to an unstable control.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an image forming apparatus not associated with the conventional drawbacks and capable of compensating for fluctuations in the image forming conditions thereby ensuring optimum image formation.

Another object of the present invention is to provide an image forming apparatus capable of modifying the amount of compensation in the image forming conditions according to the change in the characteristic of the recording member and in response to the charging hysteresis relating to the length of pause before the start of image formation.

Still another object of the present invention is to provide an image forming apparatus capable of correcting the image forming conditions in response to the fluctuation of characteristic of the recording member at the start of charging step and also to the charging hysteresis.

Still another object of the present invention is to provide an image forming apparatus capable of modifying the image forming conditions in response to the length of pause before the start of image formation, detecting the state of thus formed image and controlling the image formation according to thus detected state.

The foregoing and still other objects of the present invention will be clarified in detail from the following description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a chart showing the initial fluctuation in the charging characteristic;

FIG. **2** is a block diagram showing an apparatus embodying the present invention;

FIG. **3** is a chart showing a method for correcting the lighting voltage of a halogen lamp;

FIG. **4** is a chart showing the change in the dark potential at the start of charging;

FIG. **5** is a control flow chart of an embodiment of the present invention;

FIG. **6** is a chart showing the aberration of the dark potential from a target value immediately after the start of charging;

FIG. **7** is a chart showing a method for compensating said aberration;

FIG. 8 is a control flow chart for said compensation shown in FIG. 7;

FIG. 9A is a chart showing the control procedure for charging and exposure;

FIG. 9B is a chart showing the procedure of forming light and dark potentials in order to determine the control factor;

FIG. 10 is a block diagram showing another embodiment of the present invention; and

FIGS. 11A and 11B show a control flow chart therefor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be disclosed in detail by the following description of the preferred embodiment to be taken in conjunction with the attached drawings.

FIG. 2 schematically shows an image recording apparatus, for example an electrophotographic copier, employing the image recording control of the present invention, wherein a photosensitive drum **1** has a three-layered structure consisting of an insulating layer, a photoconductive layer and a conductive layer in the order from the external periphery thereof. Close to said drum is provided a primary charger **5** for charging the entire surface of said drum **1**. Adjacent to said primary charger **5** and along the rotating direction of said drum **1** there are provided a secondary charger or charge eliminater **6**, and a flush exposure lamp **7**. An original document **2** placed on a platen is illuminated by an exposure light source **4** such as a halogen lamp, and the reflected light is focused through an optical system **3** on said drum **1** in the vicinity of said secondary charger **6**, which eliminates the charge on the drum according to the amount of exposure, thereby forming an electrostatic latent image of the original on said drum **1**. Said latent image is further exposed entirely to the light of said flush exposure lamp **7**, thereby forming an electrostatic latent image with improved tonal rendition. Thereafter said latent image is developed with toner by a developing roller **10** in a developing station **9** according to the known jumping development process.

In the vicinity of said photosensitive drum **1** and between the flush exposure lamp **7** and the developing station **9** there is provided a surface potential sensor **8**, which measures the surface potential of the drum and transmits the measured result to a surface potential measuring circuit **12**. The output signal from said circuit **12** is converted in an A/D converter **15** and is supplied to a microcomputer **16** for data processing to be explained later. Said microcomputer **16** can be composed of a known one-chip microcomputer incorporating read-only memory, random-access memory etc., for example a device known under a model number 8049 supplied by Intel Corp. The output signals after said data processing are converted into analog signals by D/A converters **17*a*–17*d*** and supplied to high-voltage generating circuits **18**, **19**, a developing bias circuit **20** and an exposure control circuit **21** to respectively control the high voltages supplied to the primary and secondary chargers, developing bias and voltage supplied to the halogen lamp.

In such apparatus, a light potential V_{SL} corresponding to a strong light exposure and a dark potential V_D corresponding to the absence of light exposure are formed on the photosensitive drum **1** by suitably lighting and extinguishing said exposure lamp **4** or an unrepresented blank exposure lamp. Said potentials are detected by the potential sensor **8**, then converted to determined levels by the measuring circuit **12**, further converted into digital signals by the A/D converter **15** and stored in the microcomputer **16** in response to a timing signal supplied from an unrepresented sequence controller. Thus stored values are utilized for controlling the primary and secondary currents I_1, I_2 in the primary and secondary chargers **5**, **6** according to the following equations:

$$\Delta I_1 = \alpha_1 \Delta V_D + \alpha_2 \Delta V_{SL} \quad (1)$$

$$\Delta I_2 = \beta_1 \Delta V_D + \beta_2 \Delta V_{SL} \quad (2)$$

wherein ΔI_1, ΔI_2 are the amounts of variation, ΔV_D, ΔV_{SL} are the aberrations from target values, and α_1, α_2, β_1, β_2 are control factors.

Subsequent to such charging control, a light potential V_L is formed by a standard exposure, then converted in a similar manner and processed in the microcomputer **16** according to the following equation:

$$\Delta V_{HL} = \gamma_1 \Delta V_L \quad (3)$$

wherein ΔV_L is the aberration from the target and γ_1 is a constant. The output signal is supplied through the D/A converter **17*a*** to the exposure control circuit **21** for controlling the lighting voltage V_{HL} of the halogen lamp for original exposure.

Subsequent to said exposure control a light potential V'_L is formed with a standard exposure and processed in the same manner to calculate:

$$V_{DB} = V'_L + V_0 \quad (4)$$

wherein V_0 is a constant. The result of said calculation is supplied through the D/A converter **17*b*** to the developing bias circuit **20** to control the developing bias voltage V_{DB}.

The above-mentioned controls are conducted at a determined timing prior to the image forming cycle, and are capable of completely compensating the slow change in the characteristic of the photosensitive drum caused by deterioration or environmental change.

Subsequently, in response to a timing signal supplied from an unrepresented sequence controller, the microcomputer **16** measures the charging hysteresis, i.e. the charging-off period T_{OFF} and the charging-on period T_{ON} to control the voltage V_{HL} supplied to the halogen lamp for illuminating the original in the following manner. During the charging step said voltage is corrected according to the following equation:

$$V_{HL(ON)} = \Delta E(1 - e^{-t/\tau_1}) + (V_{HL} - \Delta E) \quad (5)$$

wherein ΔE indicates the correction according to the charging hysteresis, as graphically shown at the left-hand side in FIG. **3**. Also when the charging step is terminated, said voltage V_{HL} is reduced to zero by the sequence controller and is thereafter controlled according to the following equation, as graphically shown in the right-hand side in FIG. **3**:

$$V_{HL(OFF)} = \Delta E \cdot e^{-t/\tau_2} + (V_{HL} - \Delta E) \quad (6)$$

τ_1 and τ_2 in the equations (5) and (6) are time constants respectively in the order of 20 to 30 seconds and about 5 minutes.

Also, in case the charging step is initiated before the charging off period T_{OFF} reaches saturation as shown by a curve B in FIG. 3, the control is conducted according to the equation (5) except that ΔE therein is replaced by:

$$\Delta E \cdot e^{-TOFF/\tau 2} \quad (7)$$

Also, in case the charging step is terminated before the charging on period T_{ON} reaches saturation, the control is conducted according to the equation (6) except that ΔE therein is replaced by:

$$\Delta E \cdot (1-e^{-TON/\tau 1}) \quad (8)$$

The constants ΔE, τ_1 and τ_2 include fluctuations inherent to each photosensitive drum and variations caused by environmental change. Consequently, prior to the control of the halogen lamp lighting voltage according to the equations (5) to (8), said constants are calculated in a control rotation of the drum to be conducted during the warming-up period of the apparatus, warming-up period of the fixing heater, preliminary rotation of the photosensitive drum for electrostatic cleaning prior to the copying operation or during control of the latent image potential according to the aforementioned equations (1) to (4). In the present embodiment the charging-on period and charging-off period are measured by a timer provided in the microcomputer.

In the present embodiment, in case the pause between the image forming cycles exceeds 30 minutes, the dark potential is measured during said preliminary rotation or during control rotation for controlling the potential of the latent image, in order to determine the change in charging immediately after the start of the charging step thereby obtaining ΔE, τ_1 and τ_2. As shown in the control flow chart in FIG. 5, in case the copy start button is actuated at t=0 (Step **30**) after a pause longer than 30 minutes (T1), the drum rotations for charging and exposure control according to the equations (1) to (4) are effected before the image forming cycle. Subsequently, it is identified if the pause T_{OFF} is longer than T_1, and, if so, the program proceeds to the Step **32** for the measurement of the initial characteristic.

In said measurement of the initial characteristic the exposure lamp **4** or the unrepresented blank exposure lamp is extinguished immediately after the start of charging (t_0) and at determined times (t_1 and t_2) to determine the dark potentials $V_D(t_0)$, $V_D(t_1)$ and $V_D(t_2)$, from which the microcomputer **16** calculates ΔE, τ_1 and τ_2 (Step **33**) according to the following equations:

$$E_1=\Delta E(1-e^{-t1/\tau 1}) \quad (9)$$

$$E_2=\Delta E(1-e^{-t2/\tau 1}) \quad (10)$$

wherein:

$E_1=V_D(t_1)-V_D(t_0)$ and

$E_2=V_D(t_2)-V_D(t_1)$

and τ_1 is the time constant of the charging recovery characteristic. By substituting e in the equations (9) and (10) with:

$$e^x \approx 1+(x/1!)+(x^2/2!)$$

there are obtained the following approximations represented by a chain line in FIG. 4:

$$E_1 \approx \Delta E\{-(t_1/r_1)-\tfrac{1}{2}(t_1/r_1)^2\} \quad (11)$$

$$E_2 \approx \Delta E\{-(t_2/r_1)-\tfrac{1}{2}(t_2/r_1)^2\} \quad (12)$$

From (11) and (12):

$$E_1\{(t_2/r_1)+\tfrac{1}{2}(t_2/r_1)^2\}=E_2\{(t_1/r_1)+\tfrac{1}{2}(t_1/r_1)^2\}$$

from which τ_1 is determined by:

$$r_1 = \frac{-E_1t_2^2 + E_2t_1^2}{2(E_1t_2 - E_1t_1)}$$

Assuming $t_2=2t_1$:

$$r_1 = \frac{(-4E_1 + E_2)}{2(2E_1 - E_2)} \cdot t_1$$

By writing $k_1=(-4E_1+E_2)/2(2E_1-E_2)$, there is obtained:

$$\tau_1=k_1t_1 \quad (13)$$

$$\Delta E=E_1k_1(1-\tfrac{1}{2}k_1) \quad (14)$$

On the other hand the time constant τ_2 representing the charge decay after the termination of charging is given by:

$$\tau_2=k_2 \cdot \tau_1 \quad (15)$$

wherein k_2 is a constant not influenced by the fluctuation between different drums or by the environmental change and is obtained as a mean value of measurements on plural drums.

In this manner ΔE, τ_1 and τ_2 are calculated in the Step **33** and are utilized in the aforementioned exposure control in response to the charging hysteresis according to the equations (5) to (8). Subsequent to said calculation the aforementioned control according to the equations (1) to (4) to effected in the Steps **34** to **38**.

Then I_1, I_2, V_{HL} and V_{DB} determined before are respectively corrected in the Step **39** by:

$$I_1k_1\Delta E(1-e^{-t/r_1}) \quad (16)$$

$$I_2k_2\Delta E(1-e^{-t/r_1}) \quad (17)$$

$$V_{HL}K_3\Delta E(1-e^{-t/r_1}) \quad (18)$$

$$V_{DB}k_4\Delta E(1-e^{-t/r_1}) \quad (19)$$

wherein k_1 to k_4 are constants, and the copying operation is initiated in the Step **40**.

On the other hand, in case the pause T_{OFF} is shorter than T_1, the Step **41** is executed to identify if T_{OFF} is longer than T_2. Said period T_2 is so selected as to satisfy a condition $T_2>>\tau_1$ in case a condition $T_2>>\tau_2$ exists but the heater requires a considerable period for reaching a fixing state. Thus, if $T_2<T_{OFF}<T_1$, the program proceeds to the Step **34** without the measurement of the initial characteristic. In the present embodiment said period T_2 is selected as 1 minute.

In case the pause is shorter than said period Step **42** is executed to identify if the pause is longer than T_3. Said period T_3 is so selected as not to satisfy the conditions

$T_3 >> \tau_2$, $T_3 >> \tau_1$ but as to allow drum rotations for one or two turns for controlling the latent image formation and the exposure according to the equations (16) and (17), and the program proceeds to Step **37** when a condition $T_3 < T_{OFF} < T_2$ is satisfied. In the present embodiment the period T_3 is selected equal to 10 seconds.

In case $T_{OFF} < T_3$, Step **39** is executed to perform the compensation for initial fluctuation according to the equations (16) to (19).

The control according to the equations (1) to (4) in response to the aforementioned detection of the latent image potential is not conducted in real-time but is delayed by the distance from the control means to the potential sensor **8**. Also, said control cannot be executed frequently since the lamp utilized for forming the light and dark image areas requires considerably long starting and extinguishing time. For this reason the control of the latent image potential is executed in case $T_{OFF} >> \tau_2$ and when the charging time satisfies the condition $T_{ON} >> \tau_1$ after sufficient preliminary rotation during the warm-up time of the fixing heater. The optimum control value of the latent image potential is stored in the microcomputer in order to control the image formation.

Also the fluctuation in the charging characteristic resulting from charging hysteresis, giving rise to a density difference between the first and second copies in every copying operation, is compensated by correcting, according to the equations (5) to (8), the optimum image conditions obtained by the latent image potential control.

In the above-mentioned image recording control, the image potential will become aberrated from the target value if the control for the image potential is conducted during the initial period of the charging step when said fluctuation is significant. More specifically, as shown in FIG. **6**, the dark potential V_D can be brought to V_Dt_2 approximately equal to the target value V_{D0} by starting the charging at t_0, measuring the dark current V_Dt_1 at t_1 and executing the compensation at t_2 for the primary and secondary currents according to the equations (1) and (2). However the potential will become aberrated from said target value afterwards, when the initial fluctuation is terminated. Such inconvenience in the image potential control can be resolved by a method explained in the following in relation to FIG. **7**. At first ΔE is determined according to the aforementioned equations (13) to (15) by measuring V_D at t_0, t_1 and t_2. Then $V_D(T_\infty)$ is calculated and introduced into the equations (1) and (2) in place of $V_D(t_2)$, and the obtained control values for I_1, I_2 are utilized for compensation at t_3. In this manner the potential V_D arrives at the value V_Dt_3 on the target curve.

FIG. **8** shows a control flow chart showing an example of such control. In FIG. **8** the Steps **40** to **43** are the same as Steps **30** to **33** in FIG. **6** and are therefore omitted from the following explanation. The control steps shown in FIG. **7** are executed in the Steps **44** and **45**.

Subsequently, Step **46** is executed to correct the currents I_1 and I_2 according to:

$$I_1 k_1 \Delta E(1-e^{-t/\tau_1}) \text{ and}$$

$$I_2 k_2 \Delta E(1-e^{-t/\tau_1})$$

according to the charging hysteresis, wherein k_1 and k_2 are constants. The exposure and developing conditions are also corrected according to the charging hysteresis and the copying operation is initiated with such corrected conditions in Step **47**.

In case the length of pause is shorter than T_1 in the flow chart shown in FIG. **8**, the corrections are made with the preceding values without repeated measurement of the initial characteristics.

In the foregoing embodiment the recording conditions including the charging exposure and developing conditions are controlled by the latent image potential measured as a parameter indicating the surface state and the exposure condition is further corrected by the charging hysteresis, but it is also possible to omit the control on some of the recording conditions, to apply the correction according to the charging hysteresis to other condition or conditions. Furthermore it is possible to achieve similar control according to the density of the developed image in place of the latent image potential.

As explained in the foregoing, the apparatus of the present invention comprises means for measuring the charging hysteresis of the recording member, means for correcting the image recording conditions according to said charging hysteresis and means for measuring and memorizing the initial fluctuation in the charging characteristic of the recording member in the initial period of the charging step in order to modify the correction of image recording conditions determined by the measurement of surface potential in response to the memorized fluctuation and further to modify said correction according to the charging hysteresis.

In this manner the apparatus of the present invention provides the advantages of:

(1) achieving complete compensation for a rapid fluctuation in the characteristic of the photosensitive drum immediately after the start of the charging step and for a slow change in said characcteristic caused by environmental change or deterioration;

(2) avoiding an external timer circuit for measuring the charging hysteresis or a mixing circuit for the result of said measurement and the control data determined according to the latent image potential, since the charging hysteresis is measured inside the microcomputer itself;

(3) achieving compensation for the initial fluctuation caused by an environmental change, particularly by humidity change without direct measurement of the humidity; and

(4) avoiding the necessity of adjustment of ΔE and τ_1 at each drum replacement.

Furthermore, the control factors α_1, α_2, β_1 and β_2 in the foregoing equations (1) and (2) can be made variable according to certain conditions, for example according to the length of pause between charging steps or to the fluctuation between different photosensitive drums, as will be explained in the following embodiment.

In such case, as shown in FIG. **9A**, the charging control according to the equations (1) and (2) is repeated for a number of times determined for example, by a pause. For example, it is repeated four times at the start of power supply. In the first charging control the primary and secondary currents I_1, I_2 are changed in three phases to measure the light potential V_{SL} and dark potential V_D. Said control factors α_1, α_2, β_1 and β_2 are calculated from the charging characteristic of the photosensitive drum thus determined.

More specifically, as shown in FIG. **9B**, the exposure lamp **4** or an unrepresented blank exposure lamp is turned on at a high intensity during a period 0–t_3 to determine the light potential V_{SL}, and said lamp is extinguished during a period t_3–t_4 to determine the dark potential V_D.

The primary and secondary currents are adjusted to I_{10}, I_{20}, which are determined at the production of the apparatus or at the preceding control, during periods 0–t_1 and t_4–t_5, then to $I_{10}+A$ and $I_{20}+B$ during periods t_1–t_2 and t_5–t_6, and to $(I_{10}+A)+C$ and $(I_{20}+B)+D$ during periods t_2–t_3 and t_6–t_7 wherein A, B, C and D are constants. The light potentials $V_{SL}(0\text{-}t_1)=x_1$, $V_{SL}(t_1\text{-}t_2)=x_2$, $V_{SL}(t_3\text{-}t_4)$ and the dark potentials $V_D(t_4\text{-}t_5)$, $V_D(t_5\text{-}t_6)=y_2$, $V_D(t_6\text{-}t_7)=y_3$ are stored in the microcomputer **16**.

By writing $r_1=y_2-y_1$, $r_2=y_3+y_2$, $q_1=x_2-x_1$ and $q_2=x_3-x_2$, the equations (1) and (2) can be rewritten as: $A=\alpha_1r_1+\alpha_2q_1$, $B=\beta_1r_1+\beta_2q_1$, $C=\alpha_1r_2+\alpha_2q_2$ and $D=\beta_1r_2+\beta_2q_2$, so that $\alpha_1=(q_1C-q_2A)/(r_2q_1-q_2r_1)$, $\alpha_2=(Ar_2-r_1C)/(r_2q_1-q_2r_1)$, $\beta_1=(q_1D-q_2B)/(r_2q_1-q_2r_1)$, and $\beta_2=(Br_2-r_1D)/(r_2q_1-q_2r_1)$.

The control factors α_1, α_2, β_1, β_2, measured values x_1, y_1 and initial values I_{10}, I_{20} are introduced into the equations (1) and (2) to obtain second control values I_1 and I_2.

The determination of factors in the foregoing embodiment is conducted in the first charging control, but it can also be conducted in the following manner:

a. The first control is executed with the control factors predetermined at the production of the apparatus, and the factors are calculated in the second control or thereafter;

b. The control is repeated three times with determined control factors to determine the control factors;

c. Correction is made in case the control factors determined in the method b are larger than those used before. As an alternative, it is also possible to calculate the control factors a number of times and use the mean value thereof as the control factors thereafter. It is furthermore possible to indicate the necessity of drum replacement in case the control factors thus determined become smaller than predetermined values.

Furthermore, it is possible to determine the control factors by changing the exposure condition in combination with or in place of the charging condition.

As explained in the foregoing, since the control is always conducted with the control factors matching the charging characteristic of the photosensitive drum, the apparatus of the present invention allows the target potential to be reached with a reduced number of controls. Also the higher precision of control allows expansion of the tolerance for the fluctuation of performance between different photosensitive drums or for time-dependent deterioration of the drum, thus significantly extending the service life of the photosensitive drum. Furthermore the waste time for the calculation of control factors is avoided since it can be simultaneously conducted with the control itself.

Furthermore, the aforementioned control method of calculating the control factors in the control equations can also be formulated in such a manner that the image forming conditions determined by said control equations are corrected according to the charging hysteresis and the initial fluctuation in the charging characteristic.

An embodiment employing such method is shown in FIG. **10**, wherein the components are the same as those in FIG. **2** are represented by same numbers.

In this embodiment a fixing temperature sensor **11** is positioned under the photosensitive drum **1**. The signals from the surface potential sensor **8** and the temperature sensor **11** are respectively supplied to a surface potential measuring circuit **12** and a fixing temperature measuring circuit **13**, of which output signals are supplied through an analog switch **14**, converted into digital signals by an A/D converter **15** and introduced into the microcomputer **16** for data processing reflecting the surface potential and the fixing temperature as will be explained in the following.

Now reference is made to a corresponding control flow chart shown in FIG. **11**. The charging step by the chargers **5, 6** is initiated by a Step **50**. At the start of said charging step the temperature of an unrepresented fixing roller is detected by the temperature sensor **11**, temperature measuring circuit **13** and analog switch **14**, and the obtained signal is supplied through the A/D converter **15** to the microcomputer **16** for calculating the length of pause T_{OFF} after the preceding charging step from the temperature characteristic. In case the fixing roller requires a considerable period for reaching the fixing temperature, a period T_1 is so selected to satisfy a condition $T_1>>\tau_2$, and Step **51** identifies if $T_{OFF}<T_1$. In the present embodiment said period T_1 is for example selected as 30 minutes. In case the result of said identification is affirmative indicating a long pause with a significant initial fluctuation, Step **52** is executed to measure the initial characteristic. The Steps **52** and **53** are the same as the Steps **32** and **33** shown in FIG. **6**.

Subsequently Steps **54** to **56** are executed to repeat the charging control number of times as illustrated in FIG. **9A**. Said charging control is conducted by measuring, with the surface potential sensor **8**, the light potential V_{SL} formed by lighting the exposure lamp **4** with a high intensity and the dark potential V_D formed by extinguishing said lamp for calculating the charging currents according to the following equations:

$$I_1=\alpha'_1(V_D-C_1)+\alpha'_2(V_{SL}-C_2)+I_{10} \quad (20)$$

$$I_2=\beta'_1(V_D-C_1)+\beta'_2(V_{SL}-C_2)+I_{20} \quad (21)$$

wherein α'_1, α'_2, β'_1, β'_2 are constants programmed in the microcomputer **16** at the production of the apparatus, C_1, C_2 are target values of V_D and V_{SL}, and I_{10}, I_{20} are initial or previous control values.

Said charging control is terminated after a period sufficient for absorbing the initial fluctuation, namely a period satisfying the condition $T_{ON}>>\tau_1$.

After V_D and V_{SL} become sufficiently close to the target values, Step **57** is executed to calculate the control factors in the equations (20) and (21). Said calculation is conducted by measuring the light potential V_{SL} formed by an exposure with a high intensity during a period from 0 to t_3 and the dark potential V_D formed by extinguishing the exposure lamp during a period from t_3 to t_7. Also the primary and secondary currents, I_1, I_2 are adjusted to I_{10}, I_{20} which are calculated in the Step **56** in FIG. **11** during periods 0–t_1 and t_4–t_5, then to $I_{10}+A$, $I_{20}+B$ during periods t_1–t_2 and t_5–t_6, and to $(I_{10}+A)+C$, $(I_{20}+B)+C$ during periods t_2–t_3 and t_6–t_7, wherein A, B, C and D are constants. The light potentials $V_{SL}(0\text{-}t_1)=x_1$, $V_{SL}(t_1\text{-}t_2)=x_2$, $V_{SL}(t_2\text{-}t_3)=x_3$ and the dark potentials $V_D(t_4\text{-}t_5)=y_1$, $V_D(t_5\text{-}t_6)=y_2$, $V_D(t_6\text{-}t_7)=y_3$ thus formed during the period 0 to t_7 are stored in the microcomputer **16**.

By writing $r_1=y_2-y_1$, $r_2=y_3+y_2$, $q_1=x_2-x_1$ and $q_2=x_3-x_2$, the equation (8) can be rewritten as $A=\alpha_1r_1+\alpha_2q_1$, $B=\beta_1r_1+\beta_2q_1$, $C=\alpha_1r_2+\alpha_2q_2$ and $D=\beta_1r_2+\beta_2q_2$, so that $\alpha_1=(q_1C-q_2A)/(r_2q_1-q_2r_1)$, $\alpha_2=(Ar_2-r_1C)/(r_2q_1-q_2r_1)$, $\beta_1=(q_1D-q_2B)/(r_2q_1-q_2r_1)$, $\beta_2=(Br_2-r_1D)/(r_2q_1-q_2r_1)$.

The values α_1, α_2, β_1 and β_2 thus obtained are stored in the memory of the microcomputer **16** instead of the aforementioned values α'_1, α'_2, β'_1 and β'_2.

Then Step **58** is executed to measure V_D and V_{SL}, and to determine I_1 and I_2 according to the equations (20) and (21) with newly determined control factors.

Then the exposure lamp **4** is adjusted to the standard intensity for measuring the light potential V_L in the Step **59**, and the exposure control is conducted by correcting the lighting voltage V_{HL} of the exposure lamp according to an equation $\Delta V_{HL}=\gamma_1\Delta V_L$ wherein ΔV_L is the aberration in V_L. After said exposure control Step **60** is executed to again measure V_L, and Step **61** calculates the developing bias voltage V_{DE} according to an equation $V_{DE}=V_L+C_3$ wherein C_3 is a constant voltage.

In the following Step **62** the values I_1, I_2, V_{HL} and V_{DB} already obtained in the foregoing procedure are respectively corrected by the following equations:

$$I_1 + C_4\Delta E\left(1 - e^{-\frac{TOFF}{\tau 2}}\right)e^{-\frac{t}{\tau 1}} \quad (22)$$

$$I_2 + C_3\Delta E\left(1 - e^{-\frac{TOFF}{\tau 2}}\right)e^{-\frac{t}{\tau 1}} \quad (23)$$

$$V_{HL} + C_6\Delta E\left(1 - e^{-\frac{TOFF}{\tau 2}}\right)e^{-\frac{t}{\tau 1}} \quad (24)$$

$$V_{DB} + C_7\Delta E\left(1 - e^{-\frac{TOFF}{\tau 2}}\right)e^{-\frac{t}{\tau 1}} \quad (25)$$

wherein C_4–C_7 are constants. Then in the following Step **63** the image forming cycle is initiated with the charging, exposure and developing bias determined by the above-mentioned equations (22) to (25) in response to the pause T_{OFF} and the charging period t.

In case $T_{OFF}<T_1$, Step **64** is executed to identify if $T_{OFF}>T_2$, wherein the period T_2 is so determined as not to satisfy a condition $T_2>>\tau_2$ but is long enough for bringing the heater to the fixing condition, i.e. $T_2>>\tau_1$. Thus, in case $T_2<T_{OFF}<T_1$, the program proceeds to the Step **54** without the measurement of the initial characteristic. In the present embodiment the period T_2 is selected equal to 1 minute.

Also in case $T_{OFF}<T_2$, Step **65** is executed to identify if $T_{OFF}>T_3$, wherein the period T_3 is so selected as not to satisfy conditions $T_3>>\tau_2$ and $T_3>>\tau_1$ but is long enough to allow drum rotation for one or two turns for controlling the latent image potential and exposure according to the equations (20) and (21). In case $T_3<T_{OFF}<T_2$ the calculation of control factors are omitted. In the present embodiment said period T_3 is selected equal to 20 seconds.

In case $T_{OFF}<T_3$, Step **66** is executed to identify if a condition $T_{OFF}>T_4$ is satisfied, wherein the period T_4 is selected shorter than the period required for drum rotation for the control. In case $T_{OFF}<T_4$, executed is the correction for the initial fluctuation according to the equations (22) to (25). In the present embodiment the period T_4 is selected equal to 5 seconds.

In the foregoing procedure, the periods T_1 to T_4, in which the charging is interrupted, are detected by the measurement of the temperature of the fixing roller with the sensor **11** under the control of the analog switch **14**.

As detailedly explained in the foregoing, in the apparatus of the present invention, the image forming conditions determined by the control factors matching the characteristic of the photosensitive drum are corrected according to the charging hysteresis and the initial fluctuation of the charging characteristic. It is therefore rendered possible to simultaneously compensate the change in the sensitivity immediately after the start of the charging step and the change in the sensitivity resulting from a change in the environmental conditions, and to further compensate slow changes in the characteristic resulting for example from time-dependent deterioration of the photosensitive drum. Such compensations are not affected by the fluctuations between different photosensitive drums or by the environmental changes, and thus enable the avoidance of cumbersome adjustments for the various control factors in the replacement of the photosensitive drum.

What we claim is:

1. An image forming apparatus comprising:

image forming means for forming an image on a recording medium;

measuring means for measuring a sensitivity characteristic of the recording medium prior to the image formation; and

control means for detecting an image forming condition and controlling said image forming means to provide a proper image forming condition by means of performing a predetermined arithmetic processing for the detected value, said control means being adapted to determine a parameter involved in the arithmetical processing in accordance with the sensitivity characteristic measured by said measuring means.

2. An image forming apparatus according to claim **1**, wherein said correcting means corrects the parameter in accordance with a rest time period of the image forming operation.

3. An image forming apparatus according to claim **2**, wherein said correcting means corrects the parameter when said rest time period is greater than a predetermined value, and does not correct the parameter when said rest time period is less than the predetermined value.

4. An image forming apparatus according to claim **1**, wherein said image forming means includes an exposure lamp for exposing an original, and said parameter pertains to a turn on voltage of said exposure lamp.

5. An image forming apparatus according to claim **1**, wherein said image forming means includes a charger for charging said recording medium, and said parameter pertains to a charging current of said charger.

6. An image forming apparatus according to claim **1**, wherein said image forming means includes a developer for developing a latent image formed on said recording medium, and said parameter pertains to a developing bias voltage to be applied to said developer.

7. An image forming apparatus according to claim 1, wherein said control means includes detecting means for detecting a surface condition of said recording medium, and wherein said control means controls said image forming means in accordance with the output of said detecting means.

8. An image forming apparatus according to claim 7, wherein said surface condition is a surface potential of said recording medium.

9. An image forming apparatus comprising:

image forming means for forming an image on a recording medium;

detecting means for detecting a surface condition of said recording medium;

control means for controlling said image forming means so as to provide a proper image forming condition in accordance with an output of said detecting means, said control means being arranged to carry out an arithmetic processing for the output value from said detecting means in accordance with a predetermined arithmetic expression, and to operate said image forming means in accordance with the arithmetic processing result; and

correcting means for correcting the coefficient of said arithmetic expression, if said image forming means is inoperative exceeding a predetermined time.

10. An image forming apparatus according to claim 9, wherein said image forming condition is an electric charging characteristic of said recording medium.

11. An image forming apparatus according to claim 9, wherein said correcting means measures the rising variation of a sensitivity characteristic of the recording medium, and corrects the coefficient of said arithmetic expression in accordance with the measured rising characteristic.

12. An image forming apparatus according to claim 9 wherein said image forming means includes an exposure lamp for exposing an original, and said coefficient pertains to a turn on voltage of said exposure lamp.

13. An image forming apparatus according to claim 9, wherein said image forming means includes a charger for charging said recording medium, and said coefficient pertains to a charging current of said charger.

14. An image forming apparatus according to claim 9, wherein said image forming means includes a developer for developing a latent image formed in said recording medium, and said coefficient pertains to a developing bias voltage to be applied to said developer.

15. An image forming apparatus according to claim 9 wherein said surface condition is a surface potential of said recording medium.

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